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Response of Burley Tobacco to Fertilization in the Central Basin

University of Tennessee Agricultural Experiment Station

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A severe nitrogen deficiency foretells low yields of inferior cured tobacco and a low return.

Fertilizer nitrogen helps assure high yields of fine quality tobacco and profit to the grower.

The University of Tennessee Agricultural Experiment Station
John A. Ewing, Director . . . Knoxville, Tennessee

in cooperation with
Crops Research Division
Agricultural Research Service, U. S. Department of Agriculture

SUMMARY

● A fertilizer test with burley tobacco was conducted over a four-year period at the Middle Tennessee Experiment Station. The soil used for this test was Maury silt loam which was initially high in phosphorus and relatively high in potassium. Tobacco was transplanted following the turning under of a crop of rye each year. Some effects of nitrogen, phosphorus, potassium, and manure on tobacco yield, quality, value, and chemical constitution were determined.

● By using up to 120 pounds nitrogen per acre, significant improvements were obtained in yield, quality, and acre value of tobacco. Since a rye cover crop was returned to the soil each year, it is suggested that responses to even greater amounts of nitrogen may have been obtained under this particular management system had they been used.

● Increasing the nitrogen supply to tobacco tended to increase nicotine and calcium and to decrease phosphorus and potassium in the cured leaf.

● The application of 60 pounds P_2O_5 per acre was not beneficial. Rather the use of phosphorus fertilizer on this high-phosphate soil tended to depress both yield and quality evaluations of tobacco.

● Favorable responses in yield, quality, and acre value were realized by using 120 pounds K_2O per acre. This evidence suggests that a soil testing "high" in potassium by ordinary standards may not necessarily have a high enough level of this element to fully satisfy the requirements of burley tobacco.

● As fertilizer potassium was increased, analyses showed somewhat corresponding increases in potassium and decreases in calcium in cured tobacco.

● Benefits obtained from manure were outstanding. Average results showed that 10 tons manure increased tobacco yields by almost 500 pounds per acre and that manure was worth about $32.00 per ton under the prevailing conditions of the test. Manure increased the potassium content of tobacco which is beneficial, but it also supplied too much chlorine which is considered to be detrimental to tobacco used in cigarettes.

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Grateful acknowledgements are hereby made by the authors to Superintendent E. J. Chapman of the Middle Tennessee Experiment Station for his assistance in conducting the work reported in this bulletin, and to Dr. W. D. Bishop, Agronomist, University of Tennessee Agricultural Extension Service, for soil chemical evaluations.

Response of Burley Tobacco To Fertilization In The Central Basin

B. C. Nichols, D. R. Bowman, and J. E. McMurtrey, Jr.[1]

Introduction

The Central Basin area of Middle Tennessee is one of the major areas in the state where burley tobacco is grown. Many soils of this area are developed from phosphatic limestones, and therefore the soils contain abundant amounts of phosphorus available to plants. Thus, in contrast with the need for frequent replenishment of soil phosphorus in other areas, farm crops grown in the Central Basin often give little or no response to fertilizer phosphorus.

Since no previous results concerning the effects of fertilizer materials on burley tobacco grown in the Central Basin had been reported, a fertilizer experiment with this crop was initiated in 1953. This experiment was carried on for 4 years at the Middle Tennessee Experiment Station, near Spring Hill. This bulletin presents the results obtained at this location for yield, acre value, quality, and partial chemical analyses of burley tobacco when grown with 12 different fertilizer treatments.

Weather Conditions

Rainfall.—The amount and distribution of rainfall during the growing season determine to a very large extent the yield and quality of tobacco produced, providing other factors influencing growth are favorable. Too little rainfall stunts growth, hinders nutrient absorption, and results in thick, poorly-colored, cured leaf. Too much rainfall produces excessively thin leaf which is deficient in color, flavor, and aroma. Perhaps the ideal growing season is never actually realized, but conditions for plant growth and development are far more favorable in some years than in others.

Of the 4 years considered in the work reported here, the 1953 growing season was much more favorable than the other three. In 1953 there was enough rainfall during the latter part of June and all of July to stimulate vigorous growth so that relatively large yields of high quality

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[1]Authors are Agronomist, Greeneville, Tennessee; Plant Physiologist, Knoxville, Tennessee; and Physiologist, Beltsville, Maryland, respectively of the Tobacco and Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture.

tobacco were produced. The 1954 season was much too dry for adequate growing conditions, and low yields of poor quality tobacco resulted. Good yields were obtained in 1955 and 1956, but the rainfall distribution pattern in these years was such that tobacco quality was considerably inferior to that of 1953.

Rainfall by 10-day periods and monthly totals for the growing seasons 1953-1956 are giving in Table 1.

Table 1 Rainfall in Inches at Middle Tennessee Experiment Station for 10-day Intervals and Monthly Totals During the Growing Seasons 1953-1956.

Month and 10-day intervals	1953	1954	1955	1956
May 1-10	2.87	1.09	0.00	1.12
11-20	4.34	1.86	1.62	1.11
21-31	0.00	0.49	3.19	0.86
Total	7.21	3.44	4.81	3.09
June 1-10	0.02	0.79	0.63	0.45
11-20	0.51	0.08	0.98	0.65
21-30	1.07	0.00	0.47	2.89
Total	1.60	0.87	2.08	3.99
July 1-10	1.19	1.35	0.28	0.81
11-20	2.10	0.00	0.80	2.58
21-31	2.49	1.06	0.31	0.07
Total	5.78	2.41	1.39	3.46
August 1-10	0.11	0.74	2.31	0.40
11-20	0.00	0.07	2.13	1.51
21-31	0.00	0.00	0.14	1.13
Total	0.11	0.81	4.58	3.04
Sept. 1-10	0.37	0.00	0.00	1.50
11-20	1.30	0.07	0.50	0.00
21-30	0.05	1.57	1.82	0.33
Total	1.72	1.64	2.32	1.83
Total for period	16.42	9.17	15.18	15.41

Materials and Methods

Culture.—Tobacco in this test was planted in continuous culture for 4 years. While continuous culture is not usually recommended, it was employed in this instance to expedite securing effects of fertilizer materials. Rye was grown as a winter crop and turned under each spring several weeks before the tobacco was transplanted.

Fertilizers Used.—Fertilizer materials used were ammonium nitrate (33.5% N), superphosphate (20% P_2O_5), sulfate of potash (48-50% K_2O), and manure (analyses unknown.) In the first 3 years, commercial fertilizers were placed in the row with the exception that all nitrogen above 30 pounds per acre was sidedressed about 3 to 4 weeks after transplanting. All fertilizers were applied broadcast and incorporated with a disk in the fourth and final year. Manure was applied broadcast in all years.

Transplanting.—Transplanting was accomplished with a mechanical tractor-drawn transplanter. Plants were spaced 15 inches in rows 3½ feet apart. The variety Burley 1 was grown in 1953 and 1954 and Burley 21 in 1955 and 1956.

Plot Arrangement.—Test plots were arranged in a randomized block design with four replications. An individual plot consisted of eight rows 43¾ feet long. The six center rows (less end plants)—or about 1/50 acre per plot — was harvested for yield and quality evaluations.

Topping, Suckering.—Plants were topped at medium height. Suckers were removed as necessary or about two or three times each season.

Grading.—When cured, the tobacco was stripped from the stalk and separated into farm grades. Each grade of each plot was weighed to the nearest .01 pound and an appraisal of each lot was secured from the Federal Tobacco Grading Service.

Values.—Acre values were calculated on the basis of average prices paid by grade on all burley markets in the individual years considered. Grade index[2] values were compiled on the basis of prices paid for burley tobacco in the pre-war years of 1934, 1935, 1937, 1938, and 1939 and are equivalent to price per pound. Crop index values are equivalent to acre value. They were obtained by multiplying the grade index by the acre yield of each individual plot.

Analyses.—In 3 of the 4 years, 20 plants were selected at random from each plot for chemical analyses. The lug (C) grade which comes from about the center of the plant was saved from the 20-plant samples for determination of nicotine, potassium, calcium, phosphorus, and chlorine. Chemical methods used were essentially the same as previously described (3).

Soil.—The soil selected for this experiment was Maury silt loam. At the beginning of the testing period, the available phosphorus level of this soil was very high, and the exchangeable potash was approximately 200 pounds per acre. The pH range of several samples was around 6.2 to 6.8. Soil tests near the end of the testing period showed no appreciable changes in these chemical characteristics.

[2]Grade index values for all burley grades were computed by C. W. Bacon, U.S.D.A., and F. R. Wilkinson, U.S.D.A.

Experimental Results

Yields.—Data obtained for acre yields of tobacco are given in Table 2. Yields of tobacco in this experimental series were greatly influenced by the available nitrogen supply. Highly significant increases in yields were obtained by using up to 120 pounds nitrogen per acre, the maximum rate used in this test. Since adding a highly carbonaceous cover crop such as rye to the soil depletes the nitrogen supply immediately available to plants, it seems probable that a further increase in yield could have been obtained by using even more nitrogen under this particular management system.

Although the soil area employed was very high in phosphorus, 60 pounds P_2O_5 was applied to one treatment (tmt.2) to ascertain the possible need of additional fertilizer phosphorus. As shown in Table 2 no increase in tobacco yield was realized by using this additional phosphorus. Rather the use of phosphorus consistently brought about a small but insignificant repression in yield in each year of the testing period.

Considering 5-year averages, a significant increase in yield of tobacco was obtained by using 120 pounds of K_2O per acre. This was true even though the soil was "high" in potash. It is known that burley tobacco is a crop of very high potash requirement, and standards used in assessing the capacity of the soil to supply potassium to other farm crops may not necessarily be adequate for tobacco. Thus, additional potash may be needed for tobacco even on a soil that is seemingly well supplied with this nutrient.

The application of 10 tons manure per acre was very beneficial in improving tobacco yield. The use of manure in addition to a moderate amount of mixed fertilizer produced, on the average, almost 500 pounds per acre more tobacco than the mixed fertilizer alone. It seems probable in this instance that benefits derived from manure were due both to its nutrient content and to its favorable effects upon soil physical properties. The latter effect could have enhanced the more efficient use of necessary nutrients already present in the soil.

On this high-potash soil 240 pounds K_2O used in conjunction with 120 pounds nitrogen did not significantly improve yield as compared with the 180 pound K_2O application.

Quality.—Tobacco quality was evaluated in this fertilizer series by two separate means. These were (1) value per 100 pounds and (2) grade index. Value per 100 pounds represents a current account of average market prices paid by grade during the actual period in which the experiment was conducted. Grade index values, previously referred

Table 2. Fertilizer Treatments and Acre Yields (pounds) of Tobacco Grown in Fertilizer Test 1953-1956.

Tmt. no.	Pounds per acre $N-P_2O_5-K_2O$	1953	1954	1955	1956	4 Year av.
1	60-0-180	1816	1350	1871	1890	1732
2	60-60-180	1719	1347	1786	1843	1674
3	60-0-0	1592	1308	1799	1708	1602
4	60-0-60	1607	1282	1793	1700	1596
5	60-0-120	1867	1419	1924	1836	1762
6	60-0-240	1856	1436	1966	1894	1788
7	0-0-180	1272	1219	1459	1213	1291
8	30-0-180	1609	1360	1718	1653	1585
9	90-0-180	1974	1358	1899	1980	1803
10	120-0-180	2201	1550	2203	2205	2040
11	120-0-240	2261	1592	2234	2283	2093
12	60-0-180 10 tons manure	2338	1736	2341	2475	2223
	L.S.D. (.05)	329	211	191	128	122
	L.S.D. (.01)	441	NS	256	172	161

to, are relative values based on prices paid for tobacco before government support prices came into effect. Tables 3 and 4 respectively, list the data obtained for value per 100 pounds and grade index of tobacco grown in this series.

Responses by tobacco to fertilizer nutrients show similar trends regardless of which method is used for comparison in this particular experiment. On the average, highly significant improvements in both value per 100 pounds and grade index were obtained by using up to 60 pounds nitrogen per acre. Further increases in the amount of fertilizer nitrogen failed to bring about significant increases in either quality factor.

Four-year average test results indicate that adding 60 pounds of P_2O_5 to this high-phosphate soil tended to lower the quality of tobacco by both means of quality evaluation presented here. It has been observed that one effect of phosphorus is to hasten maturity of the plant. When a plant is accelerated toward physiological maturity relatively early in the growing season where severe soil moisture stresses occur, the capability of the plant to resume active growth processes when moisture becomes available is impaired. Less mature plants, not necessarily phosphorus-deficient, therefore, may be able to use late rains to greater advantage than plants that tend to mature early. This process was manifested to some degree in regard to tobacco quality in each of the last 3 years of the testing period.

Similar to its effects upon burley yields, potash was effective in significantly improving tobacco quality at rates up to 120 pounds of K_2O per acre. While yield was not reduced by using relatively large amounts of potash, it is notable that, in conjunction with 60 pounds nitrogen, the 240 pounds per acre K_2O rate significantly lowered the grade index value as compared with the 180 pound K_2O rate. The same tendency was evident in regard to value per 100 pounds, but not to the point of significance. In this respect, it is thought that the deleterious effect of the high K_2O rate on tobacco quality is most probably due to its influence in delaying plant maturity. Since all experimental plots were harvested on the same day each year, it seems plausible that tobacco grown with excessive potash was harvested when a little less mature than that grown with lower potash rates.

Effects of applying 10 tons manure in improving tobacco quality were not as decisive as in raising the yield. Manure was responsible, however, for significantly increasing the average grade index value. The same trend occurred in regard to value per 100 pounds, but not significantly so.

Adding 240 pounds of K_2O per acre in combination with 120 pounds of nitrogen failed to alter appreciably the quality of tobacco as compared with the 180 pound K_2O increment, although the tendency, as referred to earlier, was to lower quality at the higher potash rate.

Table 3. Fertilizer Treatments and Value per 100 pounds of Tobacco Grown in Fertilizer Test, 1953-1956.

Tmt. no.	Pounds per acre $N-P_2O_5-K_2O$	1953	1954	1955	1956	4 Year av.
		Dollar value per hundred pounds				
1	60-0-180	64.58	49.92	59.38	63.92	59.33
2	60-60-180	64.73	44.40	57.61	63.22	57.49
3	60-0-0	61.18	44.37	56.37	63.32	56.31
4	60-0-60	63.29	45.74	56.48	62.66	57.04
5	60-0-120	64.20	48.99	57.79	63.88	58.47
6	60-0-240	62.33	47.42	57.89	63.16	57.70
7	0-0-180	62.74	43.67	54.27	57.84	54.63
8	30-0-180	62.62	49.00	54.77	60.77	56.79
9	90-0-180	63.21	47.68	58.45	64.08	58.36
10	120-0-180	64.55	49.38	60.39	64.05	59.59
11	120-0-240	63.68	47.50	59.18	64.42	58.70
12	60-0-180 10 tons manure	65.21	52.45	60.10	64.38	60.54
	L.S.D. (.05)	2.22	5.46	1.99	1.66	1.90
	L.S.D. (.01)	NS	NS	2.67	2.23	2.50

Table 4. Fertilizer Treatments and Grade Index Values of Tobacco Grown in Fertilizer Test, 1953-1956.

Tmt. no.	Pounds per acre $N-P_2O_5-K_2O$	1953	1954	1955	1956	4 Year av.
1	60-0-180	.819	.476	.553	.510	.590
2	60-60-180	.822	.421	.470	.463	.544
3	60-0-0	.705	.401	.430	.419	.489
4	60-0-60	.736	.429	.429	.457	.513
5	60-0-120	.790	.460	.502	.510	.566
6	60-0-240	.748	.471	.499	.439	.539
7	0-0-180	.710	.422	.392	.294	.455
8	30-0-180	.736	.453	.407	.413	.502
9	90-0-180	.793	.473	.512	.544	.581
10	120-0-180	.818	.464	.609	.557	.612
11	120-0-240	.798	.458	.569	.591	.604
12	60-0-180 10 tons manure	.834	.519	.610	.632	.649
	L.S.D. (.05)	.063	.057	.092	.065	.039
	L.S.D. (.01)	.084	.076	.124	.087	.052

Acre Value.—Acre values of tobacco are determined by the products of yield and quality factors. Two methods of stating acre values are used in this publication. These are (1) dollar acre value (Table 5), and (2) crop index (Table 6).

Highly insignificant increases in both dollar value and crop index were realized by using up to 120 pounds of nitrogen per acre. This was due to the effects of nitrogen in improving both yield and quality of tobacco. As stated earlier, however, the influence of nitrogen above 60 pounds per acre was greater upon yield than upon quality.

In accordance with its tendency to lower tobacco yield and quality, 60 pounds of P_20_5 tended to reduce both the crop index and dollar acre value.

Considering 4-year average results, significant gains by both methods of determining acre value were made by applying up to 120 pounds K_2O per acre. It may be recalled here that the 240-pound K_2O increment had a depressing effect upon tobacco quality as measured by value per 100 pounds and grade index. Crop index values indicate a similar tendency but not significantly so. Average dollar acre values were almost identical for the 120, 180, and 240 pound K_2O rates. When used with 120 pounds nitrogen, 180 and 240 pounds of K_2O per acre gave similar average figures in regard to both crop index and dollar acre value.

Ten tons of manure per acre produced outstandingly beneficial results in regard to both crop index and dollar acre value. These results show that, on the average, each ton of manure applied at the specified rate increased the value of tobacco by $32 per acre.

Table 5.—Fertilizer Treatments and Acre Value of Tobacco Grown in Fertilizer Test, 1953-1956.

Tmt. no.	Pounds per acre $N\text{-}P_2O_5\text{-}K_2O$	1953	1954	1955	1956	4 Year av.
			Dollar value per acre			
1	60-0-180	1171	675	1111	1208	1041
2	60-60-180	1114	606	1029	1166	979
3	60-0-0	989	591	1107	1083	920
4	60-0-60	1017	597	1013	1065	923
5	60-0-120	1198	708	1114	1174	1049
6	60-0-240	1156	681	1140	1198	1044
7	0-0-180	804	542	798	703	712
8	30-0-180	1008	674	944	1006	908
9	90-0-180	1248	661	1113	1270	1073
10	120-0-180	1422	774	1329	1413	1235
11	120-0-240	1439	761	1324	1471	1249
12	60-0-180 10 tons manure	1527	914	1408	1594	1361
	L.S.D. (.05)	213	161	131	96	85
	L.S.D. (.01)	286	216	176	129	112

Table 6.—Fertilizer Treatments and Crop Index Values of Tobacco Grown in Fertilizer Test, 1953-1956.

Tmt. no.	Pounds per acre $N\text{-}P_2O_5\text{-}K_2O$	1953	1954	1955	1956	4 Year av.
1	60-0-180	1485	653	1030	962	1033
2	60-60-180	1414	574	846	861	924
3	60-0-0	1162	536	785	722	801
4	60-0-60	1182	560	773	775	823
5	60-0-120	1481	659	971	940	1013
6	60-0-240	1386	676	996	838	974
7	0-0-180	916	531	587	361	599
8	30-0-180	1186	623	709	689	802
9	90-0-180	1557	652	992	1082	1071
10	120-0-180	1802	723	1338	1238	1275
11	120-0-240	1801	734	1282	1350	1292
12	60-0-180 10 tons manure	1953	903	1436	1565	1464
	L.S.D. (.05)	285	143	241	146	120
	L.S.D. (.01)	382	191	323	195	159

Chemical Analyses

A partial chemical analysis of the lugs or cutter group of tobacco was made in each of 3 years of the testing period. While results obtained by evaluating only one tobacco group may not be exhaustive quantitively, information so obtained indicates the trend to be expected in tracing the effects of fertilization practices on certain chemical constituents of the tobacco leaf.

Nicotine.—Results for nicotine percentages are given in Table 7. No significant trends in nicotine content due to fertilization treatments are noted except for the nitrogen variables. Since nicotine is a nitrogen-containing compound, it is normally expected that this constituent will be present in the tobacco leaf in a somewhat direct proportion to the amount of nitrogen available to the plant (5). It is thus evident in Table 7 that nicotine in the cured leaf tended to increase with the amount of nitrogen available in the growing medium.

Ten tons of manure per acre (tmt. 12) gave only a small increase in nicotine percentage of tobacco as compared with the otherwise identical treatment (tmt. 1) which received no manure. Since manure supplies considerable nitrogen, one might expect a greater increase in nicotine content, but this limited increase has been observed by most workers who have investigated the problem. It can be explained, at least in part, by the increase in yield and consequent dilution; by the lower rate of availability of this nitrogen compared to chemical fertilizers, avoiding "luxury consumption;" by the favorable effects on the physical properties of the soil; and possibly by providing a ready supply of other plant nutrients which influence growth favorably.

Nicotine levels were lower in 1953 than in the other 2 years. Referring to rainfall data in Table 1, precipitation was more favorable for plant development in 1953 than in 1955 and 1956. The lower nicotine results for 1953 agree essentially with previous indications (8, 10, 12) that tobacco grown with ample rainfall or irrigation contains less nicotine than that grown under dry conditions.

Potassium.—A high potash content is usually associated with desirable quality in burley tobacco. As shown in Table 8, leaf potash was increased with each increment of potash added in the fertilizer. With the exception of the 1953 crop, manure (tmt. 12) was very effective in increasing the potash content of tobacco when compared with the otherwise identical treatment (tmt. 1) which received no manure.

The overall average effects of nitrogen on leaf potash content indicate that there is a tendency for the potash concentration to be reduced with an increase in fertilizer nitrogen. This was evidently due to dilution effects since substantial yield increases were realized with each addition of nitrogen.

Adding 60 pounds of P_2O_5 per acre did not materially affect the potash percentage of tobacco in this experiment.

Calcium.—The principal effect of fertilizer materials on the calcium content of the tobacco (Table 9) was due to potash variables. There was a tendency for calcium to decrease with an increase in potassium percentage in the leaf. This type of effect has been reported elsewhere (1, 2, 12), and is caused largely by calcium and potassium ions competing for entrance into the plant.

Overall, the calcium content of tobacco tended to increase with an increase in the nitrogen supplied in the fertilizer. Since the effect of increasing the nitrogen application was to lower the potassium percentage in the leaf tissues, the competing calcium ion was more efficiently absorbed at the high nitrogen levels than when the nitrogen supply was low. Similar observations were made by Garner, et.al. (5).

It has been shown that manure was very effective in introducing potash into the tobacco plant. Therefore, as would logically follow, the calcium percentage of manured tobacco was significantly lower than that grown with the corresponding treatment without manure.

Phosphorus.—The only distinct trend in phosphorus content of tobacco (Table 10) was brought about by varying the amount of fertilizer nitrogen. Leaf phosphorus decreased as the nitrogen in the fertilizer was increased. There were, perhaps, two separate influences responsible for this variation in phosphorus content.

It could be expected that the factors of dilution would play some part in reducing the phosphorus content at the higher nitrogen levels since, as previously pointed out, tobacco yields were increased with each nitrogen increment. In this regard, however, it should be noted that the soil on which this experiment was conducted was naturally very high in phosphorus, and it is not likely that a phosphorus shortage existed at any stage of plant growth. It would appear, therefore that dilution effects in reducing the leaf phosphorus percentages at higher yield levels were of a relatively minor nature.

It is more probable that the effect of nitrogen in reducing the phosphorus content of leaf tissue was because the nitrate and phosphate ions competed for entrance into plant roots. Although the nitrogen applied was half in ammonium form, nitrification proceeds rapidly in the soil under warm, moist conditions that are usually present when fertilizers for growing tobacco are applied to the soil. The abundance of nitrate nitrogen available for use by the tobacco in this test, then, was probably essentially relative to the total nitrogen applied to specified treatments.

Table 7—Percent Nicotine of the Lug (C) Grade of Tobacco*

Tmt. no.	Pounds per acre $N-P_2O_5-K_2O$	1953	1955	1956	3 Year av.
1	60-0-180	3.02	4.96	4.10	4.03
2	60-60-180	2.66	4.83	3.91	3.80
3	60-0-0	2.97	4.76	4.42	4.05
4	60-0-60	3.32	4.82	4.56	4.23
5	60-0-120	3.22	5.07	4.43	4.24
6	60-0-240	2.72	5.05	4-21	3.99
7	0-0-180	2.57	4.22	3.84	3.54
8	30-0-180	2.63	4.48	3.44	3.52
9	90-0-180	2.89	5.06	4.70	4.22
10	120-0-180	3.17	4.98	4.61	4.25
11	120-0-240	3.18	5.30	4.65	4.38
12	60-0-180 10 tons manure	3.07	4.97	4.55	4.20
	L.S.D. (.05)	0.46	0.38	0.52	0.28
	L.S.D. (.01)	0.61	0.51	0.70	0.37

* Averages of replications

Table 8.—Percent Potassium (K) of the Lug (C) Grade of Tobacco.*

Tmt. no.	Pounds per acre $N-P_2O_5-K_2O$	1953	1955	1956	3 Year av.
1	60-0-180	3.06	1.59	3.08	2.58
2	60-60-180	3.01	1.57	3.41	2.66
3	60-0-0	1.64	1.08	1.91	1.54
4	60-0-60	2.04	1.10	2.08	1.74
5	60-0-120	2.72	1.43	2.73	2.29
6	60-0-240	3.27	1.65	3.64	2.85
7	0-0-180	2.89	1.94	3.05	2.63
8	30-0-180	3.17	1.68	3.60	2.82
9	90-0-180	2.98	1.64	2.98	2.53
10	120-0-180	2.45	1.51	2.77	2.24
11	120-0-240	2.89	1.62	3.36	2.62
12	60-0-180 10 tons manure	3.00	2.40	4.81	3.40
	L.S.D. (.05)	0.55	0.22	0.31	0.31
	L.S.D. (.01)	0.73	0.29	0.42	0.41

* Averages of replications

Table 9.—Percent Calcium of the Lug (C) Grade of Tobacco.*

Tmt. no.	Pounds per acre $N-P_2O_5-K_2O$	1953	1955	1956	av.
1	60-0-180	4.76	4.84	4.05	4.55
2	60-60-180	4.82	4.92	3.98	4.57
3	60-0-0	5.46	5.12	4.95	5.18
4	60-0-60	5.17	5.10	4.69	4.99
5	60-0-120	4.85	4.75	4.24	4.61
6	60-0-240	4.64	4.73	3.91	4.43
7	0-0-180	4.42	4.45	4.21	4.36
8	30-0-180	4.20	4.60	3.67	4.16
9	90-0-180	4.90	5.11	4.26	4.76
10	120-0-180	4.96	5.16	4.41	4.84
11	120-0-240	4.80	5.20	4.30	4.77
12	60-0-180 10 tons manure	4.62	4.76	3.63	4.34
	L.S.D. (.05)	0.31	0.32	0.34	0.21
	L.S.D. (.01)	0.41	0.42	0.45	0.28

* Averages of replications

Table 10.—Percent Phosphorus of the Lug (C) Grade of Tobacco.*

Tmt. no.	Pounds per acre $N-P_2O_5-K_2O$	1953	1955	1956	av.
1	60-0-180	0.27	0.19	0.34	0.27
2	60-60-180	0.29	0.19	0.35	0.28
3	60-0-0	0.32	0.21	0.35	0.29
4	60-0-60	0.31	0.22	0.36	0.30
5	60-0-120	0.26	0.20	0.32	0.26
6	60-0-240	0.28	0.19	0.32	0.26
7	0-0-180	0.37	0.21	0.46	0.35
8	30-0-180	0.33	0.20	0.42	0.32
9	90-0-180	0.25	0.19	0.28	0.24
10	120-0-180	0.24	0.19	0.28	0.24
11	120-0-240	0.22	0.18	0.26	0.22
12	60-0-180 10 tons manure	0.28	0.18	0.29	0.25
	L.S.D. (.05)	0.05	0.01	0.03	0.02
	L.S.D. (.01)	0.06	0.02	0.04	0.03

* Averages of replications

Chlorine.—An excess of chlorine in burley tobacco is considered to be undesirable. Too much chlorine in tobacco inhibits its capacity for combustion which, in turn, lessens its value for its primary use in cigarettes. It is recommended that the chlorine content of this type of tobacco be restricted to 0.5 percent or less. Ordinarily, this can be done by the proper selection of fertilizer materials.

Although chlorine is sometimes observed to stimulate plant growth, its essentiality for plants has not become widely accepted. Recent evidence presented by Broyer, et.al. (4), however, indicates that chlorine may soon be added to the list of elements known to be necessary for the growth and reproduction of all higher plants. In any event, within certain limits, the tobacco plant is known to have the ability to absorb chlorine in a somewhat direct proportion to the amount present in the growing medium. Consequently, fertilizers high in chlorine such as muriate of potash and ammonium chloride have not been recommended for use on smoking tobacco types (2, 9, 11, 12).

As shown in Table 11, the fertilizer materials used in this series that consistently affected the chlorine content of tobacco were potash and manure. Sulphate of potash normally contains a small amount of chlorine as an impurity, and average results show that there was a tendency for the chlorine content of tobacco to increase with an increase in potash supply. Such small amounts of chlorine supplied in this manner, however, are usually of no practical consequence.

In every case manured tobacco contained several times as much chlorine as tobacco grown with commercial fertilizer alone. Previous reports concerning the ability of barnyard manure to supply chlorine to tobacco have been made (6, 12). Although tobacco is benefitted by manure in many ways, it is high in chlorine; therefore it is usually suggested that manure be used on tobacco only in moderate amounts.

Table 11.—Percent Chlorine of the Lug (C) Grade of Tobacco*

Tmt. no.	Pounds per acre $N-P_2O_5-K_2O$	1953	1955	1956	av.
1	60-0-180	0.46	0.49	0.84	0.60
2	60-60-180	0.22	0.55	0.79	0.52
3	60-0-0	0.04	0.40	0.58	0.34
4	60-0-60	0.04	0.42	0.60	0.35
5	60-0-120	0.10	0.45	0.68	0.41
6	60-0-240	0.19	0.58	0.74	0.50
7	0-0-180	0.18	0.61	0.78	0.52
8	30-0-180	0.12	0.49	1.25	0.62
9	90-0-180	0.10	0.45	0.71	0.42
10	120-0-180	0.14	0.46	0.62	0.41
11	120-0-240	0.22	0.50	0.68	0.47
12	60-0-180 10 tons manure	1.69	1.88	2.78	2.12
	L.S.D. (.05)	0.08	0.13	0.12	0.12
	L.S.D. (.01)	0.10	0.18	0.16	0.16

* Averages of replications

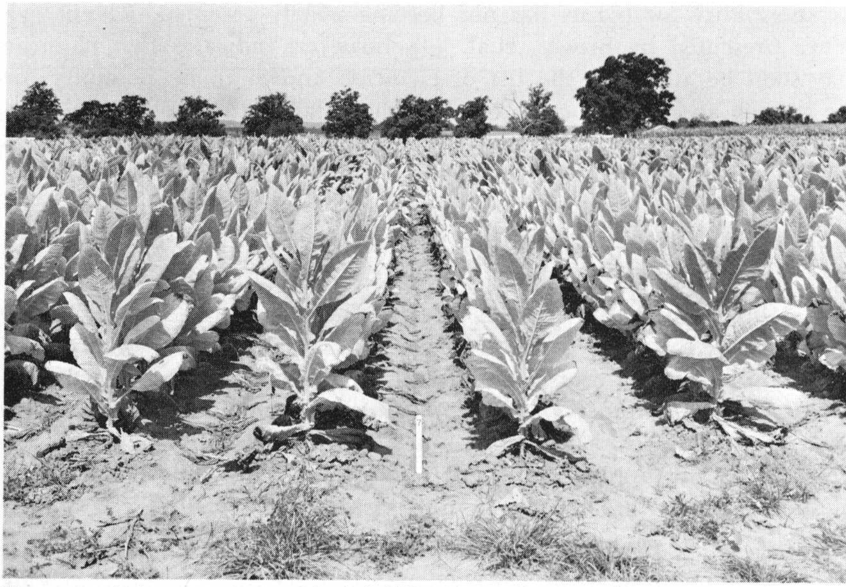

Figure 1—Tobacco grown with 0-0-180. Note nitrogen deficiency as shown by stunting of plants and general yellowing of leaves. Compare with Figure 2. Tmt. 7, 1956 Crop.

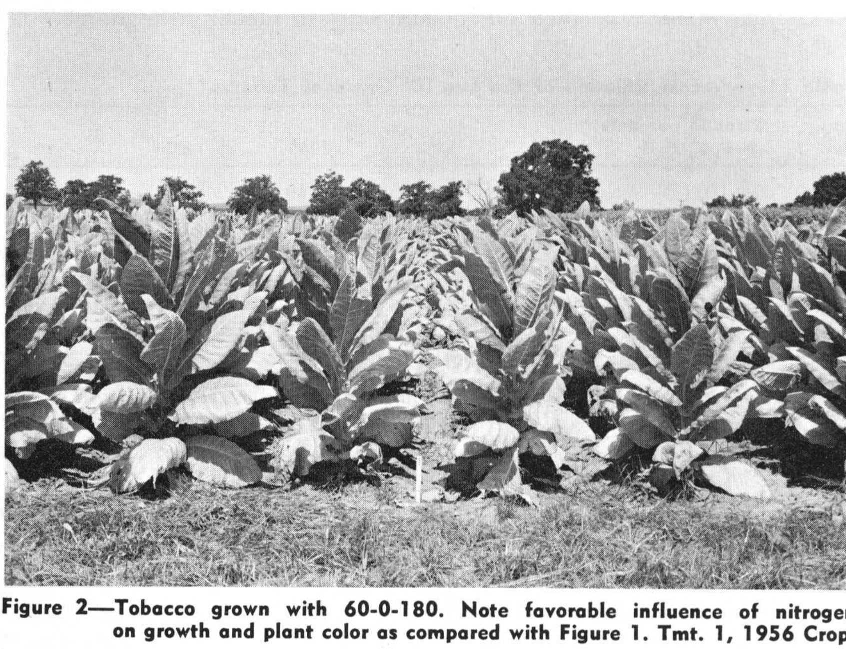

Figure 2—Tobacco grown with 60-0-180. Note favorable influence of nitrogen on growth and plant color as compared with Figure 1. Tmt. 1, 1956 Crop.

DISCUSSION OF RESULTS

Plant response to fertilizer nutrients are conditioned greatly by the inherent chemical, physical, and biological properties of the soil, by soil management practices, by climatic conditions, and by the peculiar nutrient requirements of the plant species. Perhaps all of these factors cannot be properly evaluated with the information at hand, but the influence of some are sufficiently apparent to warrant interpretation.

Effects of Nitrogen.—In this particular experiment the response to nitrogen was influenced to a large extent by the scheme of soil management employed. A cover crop of rye was turned under each year. A small grain crop such as rye is relatively high in carbon and low in nitrogen. In decomposing such material, soil microbes require more nitrogen than is present in the material itself. This extra nitrogen requirement must of necessity come from other sources in the soil. A considerable portion of the fertilizer nitrogen applied was very probably consumed by soil microbes and thus did not become available to the tobacco until late in the growing season. Under such conditions, the amount of fertilizer nitrogen needed by tobacco to obtain a given response is increased, and erroneous conclusions in regard to the need of tobacco for nitrogen under other management systems are likely to be drawn. For example, when a legume such as vetch or crimson clover is returned to the land, these legumes provide more nitrogen than is necessary for decomposition with the net result that the nitrogen applied to succeeding crops can be reduced.

Due to the comparatively large area of individual leaves, nutrient deficiency symptoms on tobacco are perhaps more prominent and spectacular than on many other farm crops. In the case of nitrogen deficiency, the whole plant turns light green in color; this is followed by a general yellowing and firing of the bottom leaves (7). As maturity is approached, the whole plant becomes yellow and many leaves may be lost. This condition is shown in Figure 1. Such tobacco is almost always low in both yield and quality.

While burley tobacco has a fairly high nitrogen requirement, it should be noted here that it is easy to provide too much nitrogen for this crop. The available nitrogen supply governs to a large extent the yield obtained, and it is frequently observed that growers have used more nitrogen on their crops than was actually needed. Such tobacco can usually be distinguished by its abnormally dark green color. High-nitrogen tobacco is hard to cure properly, and the finished leaf is dark, coarse, and too high in nicotine to be most desirable for the manufacture of cigarettes.

Table 12 is presented to briefly summarize the important effects of

Figure 3—Tobacco grown with 60-0-0. Note tendency toward restricted growth as compared with tobacco receiving potash in Figure 4. Tmt. 3, 1953 crop.

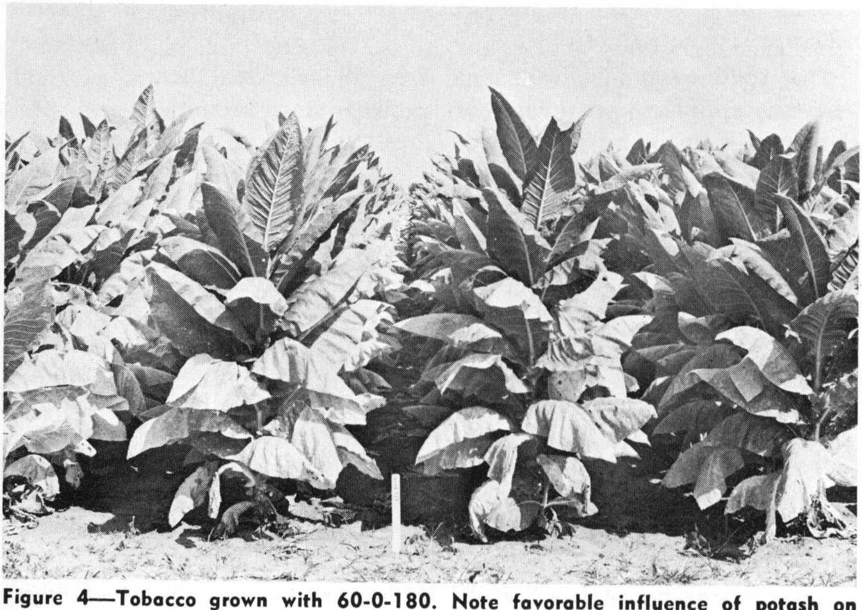

Figure 4—Tobacco grown with 60-0-180. Note favorable influence of potash on growth as compared with Figure 3. Tmt. 1, 1953 crop.

nitrogen as found in this experiment. This information shows that particular attention must be given to providing an adequate nitrogen supply if good yields of high quality burley are to be produced. Also, the nicotine percentage in the cured leaf varies somewhat directly with the nitrogen supply, and the amount of nitrogen to be supplied to tobacco must be considered very carefully if the nicotine is to be maintained at an acceptable level.

Effects of Potassium.—An adequate potassium level in the soil is usually considered to be very essential to the production of high quality burley as well as other types of tobacco. On low-potassium soils it has

Table 12.—Average Effects of Nitrogen Rates on Tobacco.

		Increase over no nitrogen					
Tmt. no.	Nitrogen per lb./A	Yield per lb./A	Value per 100 lb.	Grade index	Crop index	Acre value	Nicotine (C Grade)
			$			$	%
8	30	294	2.16	.047	203	196	-0.02
1	60	441	4.70	.135	434	329	0.49
9	90	512	3.73	.126	472	361	0.68
10	120	749	4.96	.157	676	523	0.71
L.S.D.	(.05)	140	2.00	.048	138	95	0.27

been shown previously that as much as 300 pounds of K_2O per acre may be used profitably for burley (12). On soils of medium or high potassium contents, of course, lesser amounts of potash fertilizers would be needed.

It is shown in Table 13 that even though the soil area used for this experiment was medium high in potash, favorable responses were obtained by using 120 pounds K_2O per acre. Typical potash deficiency symptoms were never observed on any of the tobacco grown in this test, but some tendency for restricted growth was noted where no fertilizer potash was applied (Figure 3). The data presented here serve to emphasize that the potash requirement of burley is exceedingly high; therefore growers may profit by being sure that their crops are well supplied with this fertilizer constituent.

Effects of Manure.—Manure obtained from farm animals has been used for fertilizing cultivated crops for many hundreds of years. Long before anything was known of the nutrient needs of plants or before commercial fertilizers came into being, the benefits of manure in stimulating plant growth were observed. At the present time where livestock

Figure 5—Tobacco grown with 60-0-180 and 10 tons manure. Note the influence of manure in promoting growth as compared with Figure 2. Tmt. 12, 1956 crop.

Figure 6—Top: Cured tobacco grown with 0-0-180 showing poor yield and color resulting from nitrogen deficiency.
Bottom: Cured tobacco grown with 120-0-180 showing improvement in color and greater preponderance of tobacco in the more useful middle grades in absence of nitrogen deficiency. Tmts. 7 and 10, 1956 crop.

is an enterprise on a particular farm, manure is regarded as a valuable source of plant nutrients. Whenever available, manure traditionally has been used as part of the fertilizer applied to burley tobacco in Tennessee. Perhaps the reasons for the popularity of using manure on tobacco can be partly understood by referring to Table 14.

Table 13.—Average Effects of Potassium Rates on Tobacco.

		Increase over no potassium						
Tmt. no.	K_2O per A.	Yield per A.	Value per 100 lb.	Grade index	Acre value	Crop index	Amount K (C Grade)	Amount Ca (C Grade)
	Lb.	Lb.	$		$		%	%
4	60	-6	0.73	.024	003	22	0.20	-0.19
5	120	160	2.16	.077	129	212	0.75	-0.57
1	180	130	3.02	.101	121	232	1.04	-0.63
6	240	186	1.39	.050	124	173	1.31	-0.75
L.S.D.	(.05)	129	2.16	.038	90	123	0.30	0.21

Throughout the testing period, manured plots showed better growth than any of the plots that received only commercial fertilizers. Figures 2 and 5 give a fair comparison of the relative growth of manured and unmanured tobacco. It is obvious that manure, as used in this experiment, was strikingly beneficial to yield, quality, and acre value of tobacco. Another favorable effect of manure was its ability to increase the potassium content of the cured leaf, which is usually considered to improve smoking quality.

On the debit side, farm manures are likely to furnish too much chlorine to tobacco which is detrimental to smoking quality. The deleterious effects of chlorine, however, are compensated for to some extent by the favorable characteristic of manure to supply potassium to the tobacco plant.

Table 14.—Average Effects of Manure on Tobacco.

Tmt. no.	Manure per acre	Yield per acre	Value per 100 lb.	Grade index	Acre value	Crop index	Amount K (C Grade)	Amount Cl (C Grade)
	Tons	Lb.	$		$		%	%
12	10	2223	60.54	.649	1361	1464	3.40	2.12
1	0	1732	59.33	.590	1041	1033	2.58	0.60
Difference	10	491	1.21	.059	320	431	0.82	1.52
L.S.D.	(.05)	129	NS	.044	84	119	0.54	0.27

Figure 7—Top: Cured tobacco grown with 60-0-180.

Bottom: Cured tobacco grown with 60-0-180 and 10 tons manure. Note favorable influence of manure on leaf size and in producing a larger proportion of tobacco in the desirable middle grades. Tmts. 1 and 12, 1956 crop.

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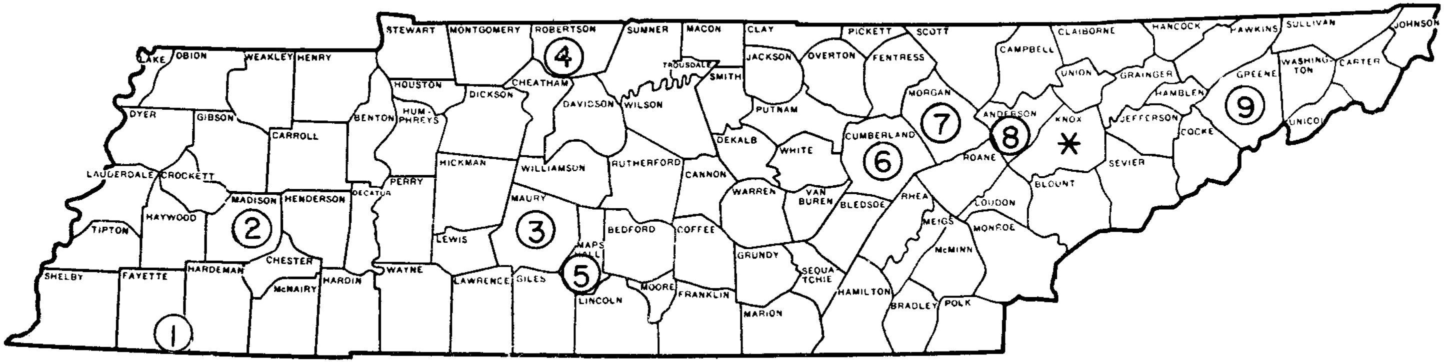

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